# ECE 198
# Design Document
# MediMinder Pro

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<u>**Needs Assessment**</u>

## Client/Customer Definition

The target customer is individuals aged 65 and above who are suffering from Alzheimer's, along with their families and caregivers. This group of individuals, along with their support network, will be the primary users and beneficiaries of the engineered medication dispenser. Alzheimer's is a type of dementia, a neurocognitive disorder that has severe effects on an individual's memory and thinking skills, worsening with time to eventually struggling to carry out simple tasks [1].

The problem that this project aims to address is the significant challenge of medication management faced by elderly individuals with Alzheimer's. The nonprofit organization MemoryLane Care Services offers care and support for people living with Alzheimer's and related disorders, and their article on medication management [2] ignited our drive to make a project in this domain. Research and information from various sources indicate that these individuals often struggle to adhere to their prescribed medication regimens due to memory issues, cognitive impairment, and the complexity of medication schedules [2]. This non-adherence can lead to severe health consequences through not meeting the required dosage and/or overdosage, increased healthcare costs, and a reduced quality of life for the elderly individuals and added stress for their families and caregivers. For this specific demographic,with several different medicines prescribed with higher dosing frequency, the chances that they are non adherent increase [3].

While the problem has been well-documented, this project will specifically focus on designing a medication dispenser to alleviate these challenges and improve medication management for this target group. The dispenser will aim to ensure the correct medications are dispensed at the right time, provide reminders, and offer ease of use for both the elderly individuals and their caregiver.

## Competitive Landscape

The primary challenge that our solution addresses is ensuring that medication among Alzheimer's patients is taken correctly and at the correct time.

System 1:
A technological system that addresses this problem is existing smart medication dispensers. Wellness Pharmacy's Karie SMART Dispenser is a popular product that manages multiple daily medications with audible reminders and automated dispensing [4]. Users can also set up facial recognition or a PIN for security and safety of the patient. The main shortcoming of this product is that it is expensive to purchase, set up, and maintain due to its many features. This can act as a barrier for low income groups that require the same assistance. Our product is designed to have much lower manufacturing costs, and thus sold at a notably lower price more suitable for the general public.

System 2: Another system that addresses this problem are traditional medication pill organizers. These pill organizers typically have compartments for each day of the week for the patient. This is a fairly user-friendly system that can be used for patients to organize and avoid missing any of their medication. The main drawback of this system is that it heavily relies on the user's memory, which is not ideal for patients with alzheimers. It can lead to confusion if the patients forget whether or not they have taken their medication, and there is no alarm or any way of reminding them. This is an evident shortcoming since “It can be very dangerous to miss doses or take extra doses of your medications” [5]. The traditional pill organizers rely completely on the patients which can easily turn into a risk, especially with our target demographic.

System 3: The final system that addresses the problem are home health services such as healthcare professionals that provide patients with their medication in their own home. This would involve healthcare workers such as nurses and caregivers. They would visit the patients homes and administer the medication and ensure that patients are receiving the right medication as well as correct doses. According to [6], “caregivers help their loved ones keep track of their medications and ensure they are taking the right dose, at the right time, for the right condition”. This system is very credible since it does not rely on the memory of the patient, but instead the healthcare worker. The major shortcoming with this system would be that the service is expensive, and not all patients can afford the healthcare professionals. Additionally, some patients may be more independent and would prefer to take their medication on their own.

## Requirement Specification

## General Requirements

- Speaker will notify customer when it’s time to have medication through a voice prompt
  - Voice prompt will be played at 55 dB, a loud but safe noise level for elderly to ensure they hear the prompt [7]
- LCD screen will be at a safe and practical brightness level of 200-400 nits. This will be sufficient since the device will be kept indoors at all times, and the screen will not need to be any larger than 400 nits [8].
- Can hold up to 7 (5x5 cm) medication containers at once. Users caregiver will insert medication capsules in the correct order which will be released into the capsule holder
- User is able to set up a 4-digit PIN via the keypad
  - Lid at top of dispenser can only be opened when correct PIN is inputted
- LCD screen has a refresh rate of 60Hz
- LCD screen and inner mechanics are able to refresh according to current function:
  - When user is setting up time intervals, they input through buttons and with the help of the LCD screen:
    - # of containers needed per day
    - Time of first dosage (in 12h format)
    - Time interval for subsequent dosage(s) (in hours)

- When medication time is equal to current time:
  - LCD screen will display a reminder message
  - Release arm will release current dosage into capsule holder

## Safety Requirements

- The dispenser should not contain more than 500mJ of energy at any point in time
- The maximum amount of power that can be used at once is 30W, to prevent overheating and harm to the customer
- All wires will be concisely organized and hidden
- Device will be grounded to prevent static electricity buildup

# <u>Analysis</u>

## Design

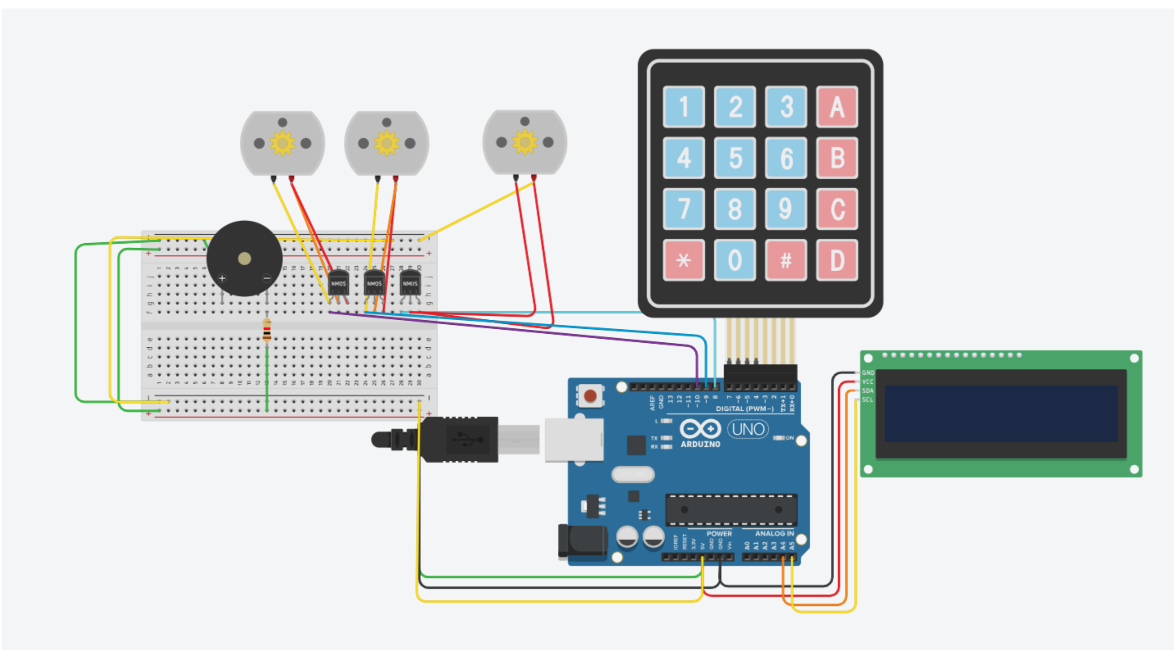


*Fig. 1 - Circuit diagram and external components*

Our design includes a 60x99x22 mm LCD screen and 12-button keypad, along with a piezo, 3 DC motors, a breadboard, and the STM32F401 microcontroller. The 5V and GND pins on the STM32 are connected to the positive and negative rails on the breadboard, these will be used to supply power to the other external components.

**Keypad:** The keypad has 8 pins that are connected directly to the microcontroller, able to send instructions digital signals directly to it. Each pin corresponds to a button on the keypad, our software will be able to identify which button was pressed.

**LCD Screen:** The GND port is connected to the STM32's GND port, and VCC is connected to the 5V port. The SDA and SCL are connected to the A4 and A5 ports, respectively.

**Piezo:** The 5V circuit runs through a 10Ω resistor before connecting to the negative terminal of the Piezo. A wire connected from the positive rail of the breadboard to the positive terminal of the piezo.

**DC Motors:** Each DC motor is connected to a transistor, each one acting as a switch for its respective motor. One motor is used for the housing door, one for the release arm, and one to open the top latch when the right PIN is inputted.

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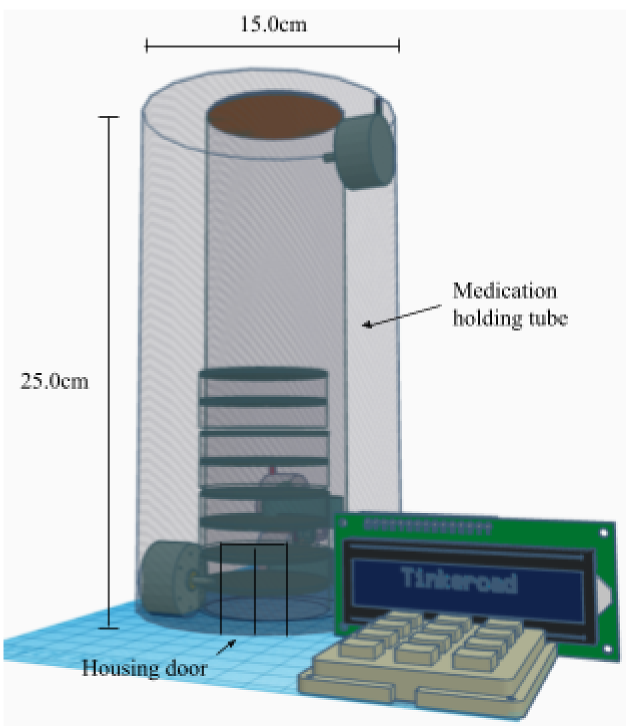


On the right is a 3D model of our dispenser, designed in TinkerCAD. All the parts and dimensions are clearly indicated and it is evident how the product will function. Our dimensions are 15cm x 25cm. The keypad, lcd, piezo, motors, and microcontroller can be clearly identified in the model.

*Fig. 2 - 3D model of dispenser*

## Scientific And Mathematical Principles

1. Newton's Second Law of motion: Newton's second law of motion describes an object's behavior where all forces are unbalanced. It explains the fact that an object's acceleration relies on the mass as well as the net force acting on the object. As the mass of an object as well as the force acting upon it increases, the acceleration decreases [9]. The equation for Newton's second law of motion is F=ma which means the force acting on an object is equal to the mass multiplied by the acceleration of the object. This principle can be directly applied to our medication dispenser since the force of gravity will be used to ensure the precise and controlled release of the medication capsules. When one container of medication is pushed out of the machine, the next container will fall into position due to gravity (Fg = mg), and will thus be ready to be pushed out at the next consumption time. The acceleration of both the medication containers and the release arm is directly proportional to the force applied by the motors, while inversely related to their mass.

2. Ohm's Law: Ohm's Law describes the relationship between voltage, current, and resistance in an electrical circuit. The formula for Ohm's Law is V=IR which means the voltage is equal to the current multiplied by the resistance in an electrical circuit [10]. This principle will be applied to the electronic part of our project. It plays a pivotal role in the proper functioning of all the electrical components. All the components in our project such as the microcontroller, breadboard, and motors all operate based on voltage and current. It will ensure a safe and reliable operation of our device, as well as proper voltage, current, and resistance levels. This knowledge will also ensure that no overheating or electrical issues occur. It will be very relevant as our inner electrical circuits and components will exploit this principle. Calculating resistance in circuits or components further ensures the reliable and controlled flow of current, contributing to the accurate and secure administration of medications through our product.

3. Interval Calculation: Time interval calculation describes the concept of dividing a large number into shorter periods of time within the same length [11]. The formula for the intervals in our project will be T(time)= Total time(24 hours) / Amount of daily doses. This principle will be fundamental in the operation of our dispenser, serving as a critical component in accurately administering the medication. To guarantee precise dosing, the dispenser's STM32 Microcontroller computes the required time intervals based on the user's programmed settings. It takes into account factors such as the number of doses per day and the specific times of administration. By utilizing the real-time clock module, the microcontroller can accurately trigger the motors to dispense medication at the

designated times. The application of time interval calculations in the dispenser ensures that patients receive their medications consistently.

## Costs

### Manufacturing Costs:

| Product | Price | Purchased from | Manufacturer | Location |
|---|---|---|---|---|
| STM32F401 Nucleo-64 Microcontroller | $34.99 | W Store, University of Waterloo | STMicroelectronics | Dutch corporation, located in Geneva, Switzerland |
| COM-14662 Keypad Switch 12 Polymer Keys | $7.73 | DigiKey Canada | SparkFun Electronics | Based in Niwot, Colorado, United States |
| LCD Screen | $14.58 | Amazon.ca | SunFounder | Based in Shenzhen, China |
| 1V-6V DC Hobby Motor Type 130 Micro Motor for Arduino | $14.18 | Amazon.ca | Gikfun | Based in China |
| 8cm x 5cm Breadboard | $8.99 | Amazon.ca | 10GTek | Based in Shenzhen, China |
| Bipolar (BJT) Transistor Array | $0.93 | DigiKey Canada | Onsemi | Based in Arizona, United States |
| CF14J-Resistor | $0.16 | DigiKey Canada | Stackpole Electronics | Based in Raleigh, North Carolina |
| 7BB-Piezo | $0.42 | DigiKey Canada | Murata Electronics | Based in Kyoto, Japan |

## Implementation Costs

Medication Dispenser Installation and User Guide

Table of Contents



## 1. Introduction

This guide is designed to help you set up and operate your MediMinder Pro effectively. Please read through this guide carefully to ensure safe and proper usage of the device.

## 2. Package Contents

- Medication Dispenser Unit
- STM32F401 Nucleo-64 Microcontroller
- COM-14662 Keypad Switch
- LCD Screen
- 1V-6V DC Hobby Motor Type 130 Micro Motor
- Power Adapter
- User Manual

## 3. System Overview

3.1 Hardware Components

- Medication Dispenser: The main unit that holds and dispenses medications.
- STM32F401 Nucleo-64 Microcontroller: The control unit that manages medication schedules.
- COM-14662 Keypad Switch: User input device for programming and interaction.
- LCD Screen: Displays medication schedules and status.

- DC Hobby Motor: Dispenses medication at scheduled times.

3.2 Software Interface

The medication dispenser system is operated via the integrated software on the STM32 microcontroller, which allows users to program medication schedules and receive notifications.

## 4. Installation

4.1 Hardware Setup

- Place the Medication Dispenser on a stable, flat surface near the user's preferred location.
- Connect the STM32F401 Nucleo-64 Microcontroller to the dispenser using the provided cables.
- Attach the COM-14662 Keypad Switch to the designated port on the dispenser.
- Connect the LCD Screen to the microcontroller.
- Insert the 1V-6V DC Hobby Motor into its designated slot.

4.2 Powering the System

- Connect the provided power adapter to the designated port on the dispenser.
- Plug the power adapter into a standard electrical outlet.
- Ensure the power indicator on the dispenser illuminates.

## 5. User Guide

5.1 Programming Medication Schedule

- Press the "Menu" button on the Keypad Switch.
- Use the keypad to input the medication schedule.
- Confirm the schedule.
- The LCD Screen will display the programmed schedule.

5.2 Dispensing Medication

- When it's time for medication, the system will automatically dispense it.
- The LCD Screen will display a notification.
- Collect the medication from the dispenser.

**6. Maintenance and Cleaning**

- Periodically clean the dispenser and components with a damp cloth.
- Ensure the DC Motor and moving parts remain unobstructed.
- Store the medication dispenser in a cool, dry place.

# Risks

## Energy Analysis

The baseline power level for the product is 13 Volts. The LCD screen uses an IIC/I2C interface, with a working voltage of 5V. The DC motors require 1V-6V of voltage, we plan to exert 3V to each one. For the keypad, based on the datasheet no voltage was listed. Therefore the assumption is made that the keypad operates at a max voltage of 5V. The piezo also had no voltage listed, but it was stated that it uses low power consumption for voltage type. We are assuming that it also operates at a max voltage of 5V. There is no chemical energy used. None of the project limits are exceeded. Our product does not consume/expend 30W of power at any given time. Our design does not contain more than 500mJ of energy at any point in time.

## Risk Analysis

**Possible Negative Consequences on Safety or the Environment from Using the Design as Intended:**

- Electrical Malfunction: One potential risk is an electrical malfunction within the medication dispenser during average use. This could lead to incorrect dosages being administered to patients, which could lead to health issues.
- If the device intakes 30W of power or more at any given time, the product will overheat and severely injure the user.
- Medication Contamination: If the medication storage area is not properly sealed or sanitized, there is a risk of contamination, which could again result in possible health issues.

**Possible Negative Consequences on Safety or the Environment from Using the Design Incorrectly:**

- Inaccurate Medication Loading: Users may load medications incorrectly into the dispenser, leading to dosing errors and potential harm to patients. This could also result in drug interactions or missed doses, affecting treatment outcomes.
- Tampering: Incorrect usage, such as tampering with the device or unauthorized access, could compromise patient safety and lead to medication misuse.

**Possible Negative Consequences on Safety or the Environment from Misusing the Design or Using it in an Unintended Manner:**

- Overdosing or Underdosing: Deliberate misuse, like overriding the dispenser's settings, could lead to severe overdosing or underdosing, with severe health effects or even fatalities.

- Environmental Impact: Discarding medication improperly or intentionally damaging the device may result in the release of meds into the environment, potentially harming ecosystems.

**Possible Ways the Design Could Malfunction:**

- Software Failures: Software glitches could lead to dosage errors or device malfunctions, impacting patient safety. The password system may malfunction, and either let an incorrect password work, or deny a correct password.
- Mechanical Failures: Mechanical components, like the dispensing mechanism, could jam or break, resulting in incorrect dosing. It could also let multiple capsules out which is a big problem that could lead to overdose.

**Consequences on Safety or the Environment for Each Failure Mechanism Specified:**

- Software Failures: If the software malfunctions, patients may receive incorrect medication dosages, potentially leading to health complications. Environmental consequences may include wasted medication if dispensed incorrectly.
- Mechanical Failures: Mechanical malfunctions can result in incorrect dosages, impacting patient safety. There's also a risk of medication contamination if the mechanical failure exposes medications to external contaminants.

## Testing and Validation

### Test #1
### Speaker Notification

**Test Setup:**
- Product will be setup with piezo buzzer, as well as LCD screen and all other components ready for user testing
- All wires will be put into proper sockets and none will be lose, since it will cause the product to stop
- Will have decibel app ready on phone in order to measure volume level

**Environmental Parameters:**
- Temperature: Maintain a constant room temperature
- Lighting: Normal indoor lighting conditions.
- Ensure that no other sound sources are active during the test to avoid interference.
- Test environment: A quiet, controlled room to minimize external noise interference.

**Test Inputs:**
- Set up the medication dispenser to go off at a certain time within the testing
- Let the buzzer go off and play noise at (55 dB).

**Quantifiable Measurement Standard:**
- Use a mobile sound level meter to measure the sound level in decibels (dB) during piezo activation
- Record the measured dB values at a consistent distance from the piezo (1 meter).
- Ensure that the dB levels do not deviate significantly from the target value of 55 dB.

**Pass Criteria:**
- The test will be considered successful if:
    - The buzzer consistently plays at the targeted sound level of 55 dB within an acceptable tolerance ( ±3 dB).
    - Buzzer is triggered at the correct time based on when it is supposed to activate
    - The test can be conducted without the involvement of human test subjects.

## Test #2
## User Input

Objective:
To validate that the Medication Dispenser correctly accepts user input through the keypad for configuring time intervals, specifically the number of containers needed per day, the time of the first dosage in 12-hour format, and the time interval for subsequent doses in hours.

Test Setup:

- The Medication dispenser is fully set up with an integrated keypad and LCD Screen. Wires are properly concealed, breadboard and microcontroller are concisely organized with all wires in the right sockets. Product should be ready for user testing.
- Test environment simulating typical usage conditions.
- Test personnel trained on device operation.

Environmental Parameters:

- Ambient temperature: 22°C
- Adequate lighting for LCD screen visibility
- Quiet environment for user interaction

Test Inputs:

- Configure the following user inputs on the Medication Dispenser:
  - Number of containers needed per day.
  - Time of the first dosage in 12-hour format.
  - Time interval for subsequent doses in hours.
- Input from the keypad should be reflected in real time on the LCD screen

Quantifiable Measurement Standard:
Test procedure:

1. Enter the number of containers needed per day.
2. Verify that the displayed number matches the user input.
3. Input the time of the first dosage in 12-hour format.
4. Confirm that the displayed time in 12-hour format aligns with the user's input.
5. Set the time interval for subsequent doses in hours.
6. LCD displays the time of the next dosage in 12-hour clock format, as well as how much time is left until set time in hours and minutes
7. Verify that the system correctly processes all inputs.

Pass Criteria:
Upon successful execution of Test 1, it will be confirmed that the Medication Dispenser accurately receives and processes user input through the Keypad for setting up time intervals, including the number of containers needed per day, the time of the first dosage in 12-hour format, and the time interval for subsequent dosages. Any discrepancies or issues will be documented for further refinement of the system.

## Test #3
## Container Capacity

Test Setup:

- The Medication dispenser is fully set up with an integrated keypad and LCD Screen. Wires are properly concealed, breadboard and microcontroller are concisely organized with all wires in the right sockets. Product should be ready for user testing.
- Medication capsules matching the designed specifications.
- Test script outlining the correct order for capsule insertion.
- A measuring device (ruler) for capsule dimensions.

Environmental Parameters:

- Temperature: Maintain a constant room temperature
- Lighting: Normal indoor lighting conditions to ensure accurate measurement .

Test Inputs:

- Prepare seven medication capsules that match the dimensions specified for the dispenser.
- Create a test script outlining the specific order in which the capsules should be inserted into the dispenser.

Quantifiable Measurement Standard:

- Measure the dimensions of the medication capsules using a ruler to ensure they match the 5x5 cm specifications.
- Record the order in which the capsules are inserted into the dispenser as per the test script.
- Ensure that the capsules fit securely into their respective slots and do not cause any jams or misalignments.
- Verify that the dispenser can hold and release all seven capsules without any issues.

Pass Criteria:

- The test will be considered successful if:
    - The dispenser is capable of securely holding all seven medication capsules simultaneously.
    - The caregiver (student) can insert the capsules in the correct order without any difficulty.
    - The capsules measurements are the same as in the requirements (5x5cm)
    - The dispenser can successfully release all seven capsules in the prescribed order.

## Test #4
## Medication distribution

Objective:
To validate that the medication dispenser correctly dispenses medication when the dosage time is reached, ensuring that the STM32 Microcontroller effectively triggers the motor to open the housing door and activates the release arm to push out the bottom-most container. Subsequent containers should fall into place, preparing for the next dosage time.

Test Setup:

- The Medication dispenser is fully set up with an integrated keypad and LCD Screen. Wires are properly concealed, breadboard and microcontroller are concisely organized with all wires in the right sockets. Product should be ready for user testing.
- Test environment simulating typical usage conditions.
- Test personnel trained on device operation.

Environmental Parameters:

- Ambient temperature: 22°C
- Adequate lighting for LCD screen visibility
- Noise level compatible with a home setting

Test Inputs:

- Configure the Medication Dispenser to dispense medication according to a programmed schedule.

Quantifiable Measurement Standard:
Test Procedure:

- Program the Medication Dispenser with a schedule that includes dispensing at a specific time.
- Observe the device when the scheduled time is reached.
- Confirm that the motor opens the housing door.

- Validate that the release arm pushes out the correct container.
- Ensure that subsequent containers fall into place, ready for the next scheduled dosage time.
- Verify that the system consistently performs these actions as per the programmed schedule.

Pass Criteria:
Upon successful execution of Test 2, it will be verified that the Medication Dispenser correctly dispenses medication when the dosage time is reached. The STM32 Microcontroller effectively triggers the motor to open the housing door, activates the release arm to push out the bottom-most container, and ensures that subsequent containers are correctly positioned for the next scheduled dosage time. Any deviations or issues will be documented for further system refinement.

**Test #5**

**Pin Key Testing**

Test Setup:

- The Medication dispenser is fully set up with an integrated keypad and LCD Screen. Wires are properly concealed, breadboard and microcontroller are concisely organized with all wires in the right sockets. Product should be ready for user testing.
- Test environment with appropriate lighting.
- A controlled setting to ensure confidentiality and security during testing.

Environmental Parameters:

- Temperature: Maintain a constant room temperature
- Lighting: Normal indoor lighting conditions.
- Ensure that no external factors affect the test environment.

Test Inputs:

- Test a range of 4-digit PIN combinations, including both correct and incorrect codes.
- Document the specific 4-digit PINs used for testing.
- Ensure the dispenser is set to its initial state for each test scenario.
- Lid should be closed for the start of the test.

Quantifiable Measurement Standard:

- Confirm that the PIN can be successfully set to a 4-digit code using the keypad.
- Verify that the dispenser recognizes and responds appropriately to the correct PIN.
- Ensure that the lid opens when the correct password is entered and stays shut for any incorrect input.

Pass Criteria:

The test will be considered successful if:

- Users can set up a 4-digit PIN via the keypad.
- The dispenser only allows the lid to be opened when the correct PIN is inputted.
- The response time for opening the lid with the correct PIN is within an acceptable range.
- Incorrect PIN entries are consistently rejected, and the dispenser maintains security.

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